Tiger shrimp farming in rice-fish farming system using salinity-tolerant rice lines

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Abstract. Rice-fish farming for tiger shrimp, *Penaeus monodon*, is a system in the rice fields, carried out simultaneously with rice plants on unproductive land due to seawater intrusion, optimizing land potential and increasing farmers' income. This study aimed to obtain rice lines that have salinity tolerance to be cultivated in an integrated manner with *P. monodon*. The research was conducted in Marana experimental pond, Maros Regency, from March to August 2019. It was carried out on 5,000 m^2 pond rice field, which was idle due to brackish water intrusion. Evaluation experiment of the rice strains was arranged in a randomized block design with four repetitions in 4x5 m^2 plot size. The test material consisted of 12 rice lines (IRIT184 and HHZ 14-SAL19-Y1) and 2 comparative varieties originating from the Indonesian Center for Rice Research (ICRR). Then, 21-day-old seedlings were planted with a spacing of 25x25 cm. The field for the strain test was in the middle of the pond, surrounded by an irrigation channel with a size of 8 m, delimiting the tiger shrimp farm. The size of the basins for each block was 650 m^2. Stocking density treatments for tiger shrimp are 2 individuals m^{-2} or 1,300 individuals $plot^{-1}$ (treatment A) and 4 individuals m^{-2} or 2,600 individuals $plot^{-1}$ (treatment B). The specimens have been previously adapted to low salinity (±5 ppt). The results after 70 days of maintenance showed that the final weight, survival and production obtained in treatment A were 13.95 g $individual^{-1}$, 54.96%, and 154.80 kg ha^{-1}, and in treatment B there were 13.45 g $individual^{-1}$, 51.05%, and 278.22 kg ha^{-1}, respectively. The final weight and survival rates between treatment A and B were not significantly different, but the production of *P. monodon* between treatment A and B was significantly different. The results of the evaluation on 14 rice lines showed that there were 2 rice lines that were able to adapt to high-salinity land (with a conductivity of 10.21 dS m^{-1}), but were not able to provide grain yield due to high panicle sterility. The results of the study indicate the need for farming technology intervention in order to increase the productivity of rice-fish farming and to obtain an optimal rice yield.
Key Words: *Penaeus monodon*, rice lines, production, salinity tolerance.

Introduction. Since the 1990s, intensive tiger shrimp (*Penaeus monodon*) farming began to face many problems, such as high mortality, slow growth rates, and crop failure due to disease-affected shrimp. As a result, many shrimp farmers left their ponds. The constraints faced were initially caused by farmers not complying with farming requirements and provisions, such as inaccurate site selection, limitation of pond area, management that was not in accordance with the carrying capacity of the land, the absence of cooperation between farmers and the spatial requirements. Other causes are also due to the increasing waste or pollution. Nowadays, many farmers, especially traditional and plus traditional fish farmers, divert shrimp farming to rice fields and ponds using low-salinity water of <10 ppt. Although their main function is to grow the rice, rice fields can also be used for tiger shrimp farming with a little addition of farming technology. Maintenance of tiger shrimp in these fields can be done without disturbing the rice planted. Therefore, it is expected that the shrimp farming conducted in the fields can increase farmers' income through rice and shrimp harvesting (Sudradjat & Wejatmiko 2010). Tiger shrimp farming is a diversification of farming that aims to increase the intensity and efficiency of land use for certain periods and zones (Zendstra 1977). In addition, it also aims to reduce the risk of crop failure, increasing the productivity and income of farmers (Sutanto et al 2000).

Rice-fish farming is not only developed in fresh water but can also be developed in brackish land. In October 2018, the Research and Human Resources Agency for Marine and Fisheries through the Program of Adaptive Technology Innovation for Brackish Water Rice-fish farming (INTAN-AP) developed the rice-fish farming technology by stocking tiger shrimp seedlings on land that was originally idle land, due to seawater intrusion in Lawallu Village, Soppengriaja District, Barru Regency, in South Sulawesi. Tiger shrimps cultivated with rice are GMO tiger shrimp born through individual selection on the growth characteristics of tiger shrimp in Brackish Aquaculture Fisheries and Fisheries Counseling Research Center of Maros. This superior tiger shrimp can also be adapted to brackish water with low salinity up to 3 ppt. The rice varieties used are Inpari 34 and Inpari 35, which are the results of breeding from the Indonesian Center for Rice Research that is able to tolerate salinity up to 7 ppt. By using this method, it is expected that land use change be reduced and the productivity of farmers and national food security increase. This study aimed to obtain salinity-tolerant rice lines to be cultivated in an integrated manner with tiger shrimp.

Material and Method. The current research was conducted in the Experimental Pond of Marana, Maros Regency, South Sulawesi from March to July 2019. This experiment used a 5,000 m^2 pond rice field, which was idle due to brackish water. The lands were divided into 4 blocks, each block containing 14 plots at a size of 4 x 5 m, so the total was 56 plots. The test material (rice lines) used in this study came from the Indonesian Center for Rice Research, Sukamandi. Each of the rice lines was planted in a predetermined plot with a spacing of 25 x 25 cm (Figure 1). The evaluation experiment of the rice lines was arranged in a randomized block design with four repetitions in 4 x 5 m^2 plot size. The test material consisted of 12 rice lines and 2 comparative varieties originating from the Indonesian Center for Rice Research (ICRR).

Table 1

The test material (rice lines)

No.	*Lines*	*Information*
1	BP14092-2b-2-1-TRT-17-3-SKI-1-B	Siak Raya/IARI 1138
2	BP14080-5b-6-5-TRT-27-4-SKI-5-B	Siak Raya/IR71991-3R-2-1
3	BP14082-2b-2-3-TRT-23-1-SKI-1-B	Siak Raya/IR68652-3B-30-2
4	IR11T184	Introduced line from IRRI
5	Bestari	Popular check variety
6	HHZ 14-SAL19-Y1	Introduced line from IRRI
7	BP14082-2b-2-5-TRT-35-5-SKI-2	Siak Raya/IR68652-3B-30-2
8	Inpari 34	Hold check
9	IR86385-38-1-1-B	Introduced line from IRRI
10	HHZ5-Sal9-Y3-Y1	Introduced line from IRRI
11	HHZ5-Sal10-DT2-DT1	Introduced line from IRRI
12	BP14092-2b-2-1-TRT-17-2-SKI-1-B	Siak Raya/IARI 1138
13	Inpari 35	Tolerant check variety
14	Mekongga	Popular check variety

In each block, there was also a 650 m^2 basin for raising *P. monodon*. The stocking density treatment for *P. monodon* was 2 individuals m^{-2} or 1,300 individuals $plot^{-1}$ (treatment A) and 4 individuals m^{-2} or 2,600 individuals $plot^{-1}$ (treatment B). Each treatment had been replicated twice (a T test was applied to the means). The seeds of *P. monodon* stocked were PL_{55} size (PL_{12} fries that had been established for 43 days; PL is post-larvae, measured in days of age) which had been adapted to low salinity (±5 ppt).

Land preparation began with the improvement of the dike, the eradication of pests' (wild fish) using 20 ppm saponins, and land preparation was carried out mechanically, with a tractor, until the land was ready for planting. To increase the pH of the soil, a 400 kg ha^{-1} agricultural lime was applied 2 weeks before planting, then basic fertilization using urea and SP36 amounted 100 kg and 75 kg ha^{-1}, respectively.

Simultaneously with the preparation of the land, a rice seedbed was carried out. Rice seeds are ready to be planted at the age of 28 days after spread. Urea fertilizer was given at a rate of 100 kg ha^{-1}, 2 weeks after planting. The third fertilizer was applied at a dose of 100 kg ha^{-1} urea at 6 weeks after planting, and the fourth fertilizer at 25 kg ha^{-1} of urea given at 5% rice flowering. Plant maintenance includes intensive weed control and pest control using bio-pesticides. In the second week after spreading shrimp, feeding level was as much as 5-3% of the weight of shrimp biomass. Rice is harvested when 90 percent of the grain is yellow or golden yellow.

The observed biological variables of *P. monodon* were length and weight growth, while for rice plants, plant height and number of tillers. Both of them were observed every two weeks. The survival rate, shrimp production, and rice lines production were calculated after the end of the study. Water quality variables included temperature, dissolved oxygen, salinity, pH and alkalinity, which were observed every week, while dissolved organic matter, ammonia, nitrite, nitrate and phosphate were observed every two weeks. Survival rate, shrimp production, and rice lines production were analyzed using statistical tools, while the water quality and plankton variables were analyzed descriptively. The data obtained were analyzed using ANOVA SPSS program.

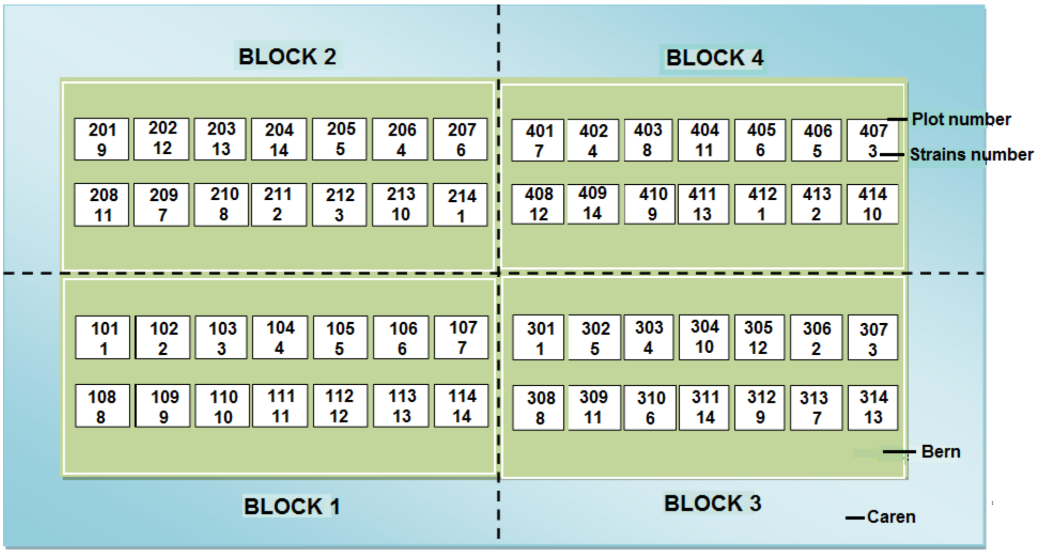

Figure 1. Research layout.

Results and Discussion

P. monodon. The results of weight growth sampling of *P. monodon* conducted every 2 weeks for 70 days of maintenance can be seen in Figure 2. The weight of *P. monodon* increased in a relatively constant rhythm until the 70^{th} day of maintenance, from an average initial weight of 0.2 g $individual^{-1}$ to 13.95 g $individual^{-1}$ (treatment A) and 0.2 g $individual^{-1}$ to 13.45 g $individual^{-1}$ (treatment B). T Test results showed that differences in stocking densities between treatments do not have a significant effect (P>0.05) on the final weight growth. This means there is no competition in the use of space, food, and dissolved oxygen that can affect the growth of the final weight of tiger shrimp. High density stocking causes competition for space, food, and dissolved oxygen so that it can result in stunted growth and even in death causing extreme conditions.

Stocking density is the number of *P. monodon* stocked in one square meter of pond land and is related to farming productivity. The closer to optimal the level of stocking density in the farming process, the higher the level of the farming productivity (Hudi & Shahab 2005). The safe (optimal) stocking density for extensive plus *P. monodon* farming is 4 individual m^{-2}, due to an oxygen content above 3 mg L^{-1} during maintenance, while the average final weight and survival rate are higher than the stocking densities of 6 and 8 individual m^{-2} and the production difference between the three stocking densities is not significantly different (Mansur et al 2004).

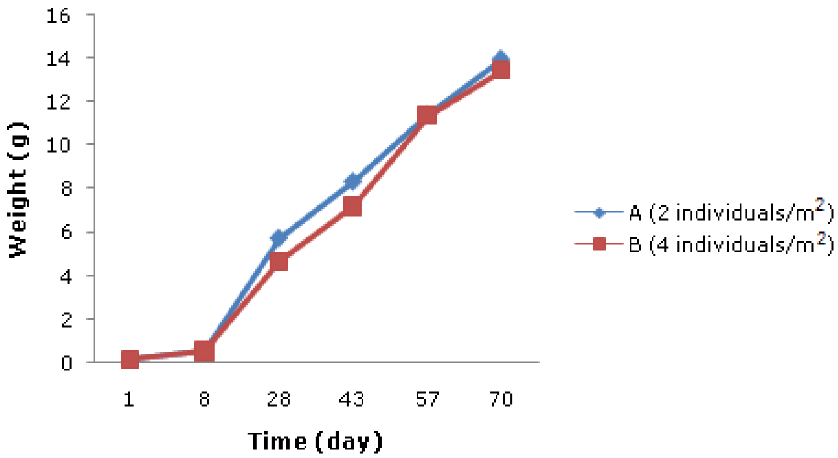

Figure 2. Growth rate of *Penaeus monodon* for 70 days of culture period.

The survival rate and production of *P. monodon* obtained in treatment A were 54.96% and 154.80 kg ha^{-1}, while those of treatment B were 51.05% and 278.22 kg ha^{-1}, respectively. T test results showed that the survival rate of tiger shrimp between treatment A and treatment B was not significantly different ($P>0.05$), but the production of tiger shrimp between treatment A and treatment B was significantly different ($P<0.05$). According to the final weight data, survival and production of tiger prawns during 70 days of maintenance (Table 2) showed that the higher the stocking density, the higher the yields, but the survival rate and size of the shrimp harvested were relatively lower. This is in line with a research conducted by Darmono (1991) stating that under-stocking will result in low production, even though the size of each fish is larger. On the contrary, if the stocking is too high, it will cause the size of each tail to be small, even though the production increases. It is further explained that the density of *P. monodon* depends on the type of shrimp at the size of the fry (when stocked). Moreover, the density also depends on the ability of a container or pool to accommodate a number of individual organisms maintained and on the manner these organisms continue their lives.

Table 2

Growth rate, survival rate, production and FCR of *Penaeus monodon* for 70 days culture period

Variable	*Treatment*	
	A (2 individual m^{-2})	*B (4 individual m^{-2})*
Stocking densities (individual $pond^{-1}$)	1.300	2.600
Time culture (days)	70	70
Initial weight (g $individual^{-1}$)	0.2	0.2
Final weight (g $individual^{-1}$)	13.95^a	13.45^a
Survival rate (%)	54.96^a	51.05^a
Production (kg $pond^{-1}$)	10.06	18.09
(kg ha^{-1})	154.80^a	278.22^b
Feed conversion ratio	1.65^a	1.56^a

Average value in a column or row with the same superscript letter indicates not significantly different ($P>0.05$).

The final weight, survival and production of *P. monodon* obtained in this study are lower than tiger shrimp yield with extensive plus patterns cultivated with a modular system in the pond for three and a half months of maintenance with a stocking density of 4 individuals m^{-2}. It shows that the average final weight is 21.61 g $individual^{-1}$, survival rate is 72.43%, and production is 629.2 kg ha^{-1} (Mansur et al 2004). The results are also lower than the harvest of tiger shrimp using fries that kept for 1 month. The results show that the production is 1,073.2 kg ha^{-1}, survival rate is 86.20%, the average weight is 31.14 g $shrimp^{-1}$. Likewise, the results of fries not kept (direct stocking of fry) are also lower, namely the production is 677.2 kg ha^{-1}, survival rate is 61.97%, the average weight is 27.33 g $shrimp^{-1}$ on a stocking density of 4 shrimp m^{-2} for 85 days of maintenance on a pond (Mustafa & Mangampa 1990). The low survival rate and production of *P. monodon* in the present study are due to the continuous attacks of white spot disease (WSSV) on the shrimp, forcing the harvesting on the 70th day of maintenance. This disease also attacks tiger shrimp ponds around the research location. WSSV infection in tiger shrimp, a major problem in the global shrimp industry, especially in Southeast Asia (Rajendran et al 1999), is a common disease affecting tiger shrimp production (Flegel 1996). White spot is a disease that causes high economic losses, which is estimated at more than 300 million US dollars per year (Rukyani 2000). Transmission of WSSV is very fast and causes 100% death within 3-10 days from the occurrence of clinical symptoms. This virus can infect shrimp in post larvae (PL) up to 40 g of its size. WSSV can be spread vertically through the broodstock transmitting to the larvae and horizontally through water (waterborne transmission), infected shrimp dung, cannibalism, crustacean fresh food, and crustaceans of pond pests (Kono et al 2004). In farming systems, WSSV can be transmitted through contaminated water (Chang et al 1996).

Feed conversion ratio is one indicator to assess the feed efficiency. The value of the conversion ratio of tiger shrimp feed in treatment A is 1.65 and treatment B is 1.56. T test results show that feed conversion ratio between treatment A and treatment B is not significantly different ($P>0.05$). The value of Feed Conversion Ratio obtained in this study is good. A good feed conversion ratio for white leg shrimp is 1:1 to 1:1.5 (Haliman & Adijaya 2005), while for tiger shrimp is up to 1:1.6 (Briggs et al 2004). Pascual (1984) states that the lower the value of feed conversion ratio, the better the feed will be. It is because only a small amount of feed is needed to produce a certain weight of an organism. The size of the feed conversion ratio is influenced by several factors, but the most important are quality and quantity of feed, species, size and water quality. The value of the feed conversion ratio determines the effectiveness of the feed (NRC 1993).

The observed water quality parameters, such as temperature, dissolved oxygen, pH, and salinity, show relatively similar values in both treatments (Table 3). The range of water quality parameters is able to support the growth and life of tiger shrimp. The suitable water temperature for tiger shrimp farming is 26-32^{0}C and the optimum range is 29-30^{0}C (Poernomo 1988). Tiger prawns are able to live in a salinity range of 3–45 ppt even with slow changes, they can still live up to 50 ppt (Cholik & Poernomo 1987).

The limit of dissolved oxygen for *P. monodon* is 3-10 mg L^{-1} and 4-7 mg L^{-1} at the optimum limit (Poernomo 1989). A good pH range for tiger shrimp is 7.5-8.7 with an optimum at 8.0-8.5 (Poernomo 1988). A pH value of less than 5 causes the clumping of mucus on the gills and shrimp suffocation (Soetomo 2000). However, pH above 9 will increase levels of ammonia which can kill shrimp (Tricahyo 1994). Table 2 shows that the pH range of water during maintenance is neutral to basic.

The measured salinity in treatment A and treatment B ranged from 4-9 ppt is classified as low for tiger shrimp because the water used came from rain water collected in a reservoir of 5,000 m^2. This is a condition included in the requirements of rice-fish farming. A salinity of 4 ppt occurs at the beginning of maintenance and salinity fluctuations tend to increase over the maintenance time. The increase in salinity is due to season change from rainy to dry season, which increases evaporation. For an optimal growth, a salinity ranging between 15 and 25 ppt is required.

In treatment A, alkalinity is 93.05-133.25 mg L^{-1} and in treatment B it is 86.54-137.35 mg L^{-1}, including the optimal values for growth of tiger shrimp. According to Adiwijaya et al (2003), the values range of alkalinity for the optimal growth of shrimp is 90-150 mg L^{-1}.

Table 3

Water quality value

Variable	Treatment	
	A (2 individual m^{-2})	B (4 individual m^{-2})
Temperature(°C)	25.35-30.55	25.9-30.70
Dissolved oxygen (mg L^{-1})	2.88-6.43	2.41-6.43
pH	8-9	8-9
Salinity (ppt)	4-9	4-9
Alkalinity (mg L^{-1})	93.05-133.25	86.54-137.35
Dissolved organic matter (mg L^{-1})	35.31-69.79	33.43-74.98
Ammonia (mg L^{-1})	0.012-0.023	0.011-0.020
Nitrite (mg L^{-1})	0.0008-0.0118	0.001-0.0067
Nitrate (mg L^{-1})	0.0713-3.1636	0.0980-2.9116
Phosphate (mg L^{-1})	0.0010-0.6219	0.0139–0.5771

The measured values of dissolved organic matter content in treatment A and treatment B are quite high, ranging from 35.31 to 69.79 mg L^{-1} and from 33.43 to 74.98 mg L^{-1}, respectively. The high total organic material originates from *Chara* sp. water algae, grass and decomposed leaves litter, dried and processed on the ground using a tractor. The content of dissolved organic matter in normal waters is at maximum of 15 mg L^{-1}. If the content of dissolved organic matter is high, it can reduce the dissolved oxygen content in water due to its consumption by the decomposition process of organic material (Boyd 1990). Dissolved organic matter should not exceed 20 mg L^{-1}. Dissolved organic matter content that exceeds 20 mg L^{-1}, in addition to triggering the proliferation of *Vibrio* spp., also allows the virus (especially WSSV) to attack those shrimp specimens that are weakened due to various stressors (Madeali et al 2009).

The main source of ammonia is organic material in the form of leftovers, shrimp dung, plankton, and suspended organic matter (Ahmad 1992). Ammonia content in treatment A is 0.012-0.023 mg L^{-1} and ammonia in treatment B is 0.011-0.020 mg L^{-1}. The range is still suitable for *P. monodon* farming. The maximum level of NH_3 that is still safe for shrimp is 0.1 ppm (Wickins 1976). A NH_3 concentration of 0.5 ppm can reduce shrimp growth by 50% (Ahmad 1988).

Nitrite content in treatment A is 0.0008-0.0118 mg L^{-1} and nitrite content in treatment B is 0.001-0067 mg L^{-1}, which is still below the threshold and categorized as quite low, but still within the criteria of safe life for *P. monodon*. According to Schmittou (1991), a nitrite concentration of 0.1 mg L^{-1} can cause stress in aquatic organisms. Concentrations of 1.00 mg L^{-1} can cause death. Nitrite is a transitional form between ammonia and nitrate through the process of nitrification, as well as between nitrate and hydrogen gas through the denitrification process. Nitrite concentration is smaller than nitrates because nitrites are not stable if there is oxygen (Boyd 1992). Natural waters contain NO_2, which is around 0.001 mg L^{-1}, and it does not exceed 0.06 mg L^{-1} (Canadian Council of Resources and Environment Ministers 1987). In waters, NO_2 concentration rarely exceeds 1 mg L^{-1} (Sawyer & McCarty 1978). A NO_2 concentration of more than 0.05 mg L^{-1} can be toxic to very sensitive aquatic organisms (Moore 1991).

Nitrate content in treatment A is 0.0713-3.1636 mg L^{-1} and in treatment B is 0.0980-2.9116 mg L^{-1}. This value is sufficient to support the growth of natural feed in shrimp cultivation plots. Nitrate is the main form of nitrogen in natural waters, needed by aquatic plants (algae), soluble in water, and stable. Nitrate content needed for algae growth in waters is 0.2-0.9 mg L^{-1} and at the optimal range of 0.1-4.5 mg L^{-1} (Effendi 2003). The optimal nitrate concentration for shrimp is 0.4-0.8 mg L^{-1} (Clifford 1994). Nitrate is a limiting factor if the concentration <0.1 mg L^{-1} and >4.5 mg L^{-1} (Azman 2005).

Phosphate content in treatment A is 0.0010-0.6219 mg L^{-1} and phosphate content in treatment B is 0.0139-0.5771 mg L^{-1}. The phosphate concentration is classified as oligotrophic (low) to hypetrophic (fertile), according to the statement of Hakanson & Bryann (2008), that phosphate concentration has a relationship with the fertility level of waters. Phosphate concentration of 0.040-0.130 mg L^{-1} is included in the category of eutrophic waters, while phosphate concentration >0.130 mg L^{-1} is included in the category of hypertrophic waters. According to Wardoyo (1982), the optimal range of phosphate content in waters is 0.101-0.211 mg L^{-1}. If the phosphate content is large enough to exceed the normal requirements of plant-based organisms, the waters will be too fertile (eutrophication). If this condition is supported by the presence of other nutrients, it will stimulate the growth of abundant plankton.

Rice plant. Rice plants are sensitive to salinity stress. However, the plant is recommended to be cultivated on saline soil because of its ability to adapt to inundation conditions and to wash salt in the land. Rice plant is sensitive to salinity in the nursery and generative phases, but tolerant in the seedling and seed maturation phases. Utilization of idle land for rice-fish farming requires rice varieties that are very tolerant of salinity stress, both in the vegetative and generative phases. Until now, no varieties have been reported to be as tolerant during the generative phase. This study evaluates the aspect of rice lines in salinity-tolerant ponds, where the salinity stress tends to increase, in absence of desalinization interventions on the land.

This experiment is carried out in the dry season. During the trial period, rain never occurred, so the conditions of water and land salinity were increasing. During the transplanting process, the water in the basin has a salinity of about 6 dS m^{-1}. The results of the soil analysis show that the pond used has a dominant sandy clay texture. The results showed that the salinity of the experimental rice field was classified as high when transplanting, and very high when harvesting. According to Hardie & Doyle (2012), electrical conductivity (EC) values of 1-2 dS m^{-1} in a clay soil extract of 1:5 soil-water ratio are associated with electrical conductivity values of 8-16 in saturated paste extract (ECe) condition, while Ec values of 2-4 dS m^{-1} are associated with an ECe value of 16-32 dS m^{-1} (land with very high salinity classification). According to Sonmez et al (2008), the conversion rate for EC values at a ratio of 1:5 to the saturated extract condition has the equation ECe=7.36z-0.24 (z is values measured in (1:5) soil to water ratios). Therefore, the ECe value is 11.02 dS m^{-1} when transplanting and 25.00 dS m^{-1} when harvesting. In sandy soil, the value will be even higher.

Based on the observation in the field, it was determined that the lines tested are not able to survive in the saline condition of the experimental site. The two lines tested, including check varieties, experienced adaptation problems since the early growth phase. For example, on the 14^{th} day, only 40% of the lines survived in the saline condition. Replanting is done to replace the dead seeds. However, plants suffered from salt poisoning, which is indicated by dry leaves, even in flooded condition. This is reasonable because inundation also has sufficient salinity to interfere with growth. The plants suffered salt stress during the growth duration, from seedling to harvesting, indicated by the EC value at the seedling stage of water in the seedbed and pond about 6.5 dSm^{-1} (data not shown), while the ECe value in the soil was above 11-25 dSm^{-1} (Table 4 and Table 5). The electrical conductivity of 3.5 dS m^{-1} is able to disrupt the growth and development of rice plants. The threshold of the EC value of water that can still be used by tolerant plants is around 3-7.5 dS m^{-1} (USDA). All of the 14 rice lines tested experienced crop failure. The observation revealed that they experienced growth disturbance and they were not able to produce rice seeds 8 days after planting. Even after the replacement of the dead plants their growth remained abnormal as it could be seen in the color of the dry leaves, in the low number of tillers and ultimately in their reproductive incapacity (high panicle sterility) (Figure 3). The experimental field was in anaerobic saline condition during planting to harvesting. The map used in this study was the former pond that has been used for whiteleg shrimp (*Penaeus vannamei*) farming and has never been used for rice.

Table 4

Soil analysis during transplanting and during the generative phase of the plant (harvest)

Location	*Extract 1:5*	*Salinity*	*pH*		*pH NaF**		*Total (HNO_3); (dry sample 105°C)*											
	EC dS m^{-1}	mg L^{-1}	*H_2O*	*KCl*	*1**	*60**	*P*	*K*	*Ca*	*Mg*	*Na*	*S*	*Fe*	*Al*	*Mn*	*Cu*	*Zn*	*B*
Maros-transplanting	1.53	762			8.9	9	0.06	0.25	0.62	0.58	0.3	0.01	3.88	5	264	55	63	14
Maros-generative (harvesting)	3.43	1714	5.9	5.5	8.8	9.1	0.07	0.36	0.4	0.76	0.42	0.17	5.36	4.05	446	63	104	54

Table 5

Soil analysis during transplanting and during the generative phase of the plant (harvest)

Location	*Soil texture 4 fraction*			
	Sand *50 μm - 20 mm*	*Dust* *2-50 μm*	*Rough clay* *0.2-2 μm*	*Fine clay* *<0.2-2μm*
Maros-transplanting	4.3	39.1	13	43.6
Maros-generative (harvesting)	9.4	44	17.6	29

Figure 3. The performance of rice plants in the research plot (saline land) compared to rice fields (as control), with the same seed source (original).

In the present study, although the lines tested are not able to produce grains due to high sterility, there are indications that two lines have a higher adaptability than other lines at the salinity level of the experimental field. These lines are strain No. 4 (IRRI184) and HHZ 14-SAL19-Y1.

Generative phase is the phase the most sensitive to the salinity stress. In general, the productivity of rice varieties will decrease to 50% at an ECe level of 7.2 dS m^{-1} (Umali 1993). Production will decrease by 12% for an increase of 1 dS m^{-1}. Therefore, the lines tested are not able to survive at the salinity level of the experimental field. This indicates that the practice of tiger shrimp farming requires the availability of very tolerant varieties in the generative phase. In other words, if the tolerant varieties currently available do not meet the desired requirements, land management is needed to reduce salinity without interfering with shrimp growth.

One of the parameters that can be used to assess the level of soil salinity is to measure the electrical conductivity (EC) of a solution extracted from the soil. Pure water is a very poor conductor of electricity. However, the conductivity of electricity will increase with increasing salt content in the water. Measuring EC of a soil solution means that salt content is indirectly measured. The commonly used unit is deciSiemens m^{-1} (dS m^{-1}) (Rachman et al 2018). Electrical conductivity reflects dissolved salt level, so an increase in salt content affects an increase in the value of electric conductivity (Eviati & Sulaeman 2009).

Based on the soil analysis criteria at the research location, namely EC, that reached 10.21 dS m^{-1}, and exchanged sodium cations about 17 and 21.7% at seedling stage (transplanting) and generative stage (harvesting), respectively, criteria for the soil salinity was considered very high. Soil is said to have a very low salinity if it contains less than 0.1 me 100 g^{-1} cations, the electrical conductivity is <1 dS m^{-1} and exchanged sodiumis <2%. Land is said to have a low salinity if it contains 0.1-0.3 me 100 g^{-1} cations, the electrical conductivity is 1-2 dS m^{-1} and exchanged sodium isranges from 2 to 4%. Soil is said to have medium salinity if it contains 0.4-0.7 me 100 g^{-1} cations, the electrical conductivity is 2-3 dS m^{-1}, and sodium can be exchanged for 5-10%. Soil is said to have high salinity if it contains 0.8-1.0 me 100 g^{-1} cations, the electrical conductivity is 3-4 dS m^{-1}, and sodium can be exchanged for 10-15%. Soil is said to have a very high salinity if it contains >1.0 me 100 g^{-1} cations, electrical conductivity is >4 dS m^{-1}, and sodium can be exchanged for 15% (Eviati & Sulaeman 2009). The main cause of failure in plant rice exposed to the high sodium concentration in soil, characterized by a high electrical conductivity (EC) value and a sodium saturation (TDS=total dissolved salt). Studies on electrical conductivity have been carried out. One of the results is that the increase of electrical conductivity in rice soil greatly decreases the rice yield. An increase in EC up to 4 dS m^{-1} causes very low rice yield or may completely inhibit rice production (Rachman et al 2018).

Salinity is an environmental factor that influences plant growth and productivity. Growth obstacles due to the salinity stress experienced by rice plants in this study include changes in leaf color, suboptimal plant height, a small number of tillers and even plants that do not produce seeds. According to Rachman et al (2018), a high saline soil solution in the plant root area will increase the osmotic pressure so that plant roots will have difficulty in absorbing water, resulting in physiological dryness. When the concentration of salt in the soil is quite high, the water in the plant cells will move out, the protoplasmic walls will shrink and the cells will be damaged (plasmolysis). In addition to plants having to cope with high osmotic pressure, some plants may experience nutrient imbalance due to certain nutrient levels being too high. Furthermore, Djukri (2009) stated that plants that live in saline land experience major issues, such as: (1) the higher negative groundwater potential will spur water out of the tissue, so that plants lose turgor pressure; and (2) the high concentrations of sodium ($Na+$) and chloride ($Cl-$) ions are likely to be toxic. The abundance of $Na+$ and $Cl-$ also cause ion imbalance so that metabolic activity in the body of the plant is disturbed.

Figure 4A shows the difference between the heights of the rice planted in the research plot and the height of rice planted in the rice field (as a control). The rice planted in the research plot reached only 70 cm, with the empty rice grains (Figure 4B), while the rice planted in rice fields reach 120 cm with a higher number and weight of grains. Figure 4C shows differences in the condition of the roots of rice plants: in rice fields, root grow deeper into the soil, while in the research plots root grow on the surface of the soil, as a form of adaptation of rice roots to avoid high soil salinity. NaCl effect can reduce the number of tillers, root length, plant height, canopy dry weight, roots and total plants (Suwarno 1985). The higher the electrical conductivity, the the lower the chance of obtaining grains. In salinity sensitive rice plants, the grain yield will be limited to less or no grain at all. Therefore, water for irrigation on saline rice fields should use fresh water at very low EC, to be able to minimize sodium concentration. The key to successfully overcoming salinity is to dilute sodium and transfer it to a body of water (Rachman et al 2018).

Figure 4. Differences in plant height, grain and root conditions between rice plants on research plot (saline land) with rice plants on rice fields (as control) with the same seed source (original).

Conclusions. The final weight, survival rate, and production of tiger shrimps obtained in treatment A are 13.95 g individual^{-1}, 54.96%, and 154.80 kg ha^{-1}, respectively. In treatment B, the final weight, survival rate, and production of tiger shrimps are 13.45 g per individual^{-1}, 51.05% and 278.22 kg ha^{-1}. The final weight and survival rate of tiger shrimp between treatment A and treatment B are not significantly different, but the production of tiger shrimp between treatment A and treatment B is significantly different.

The results of the evaluation on 14 rice lines tested showed that the two rice lines are able to adapt to high-salinity land (10.21 dS m^{-1}), but they are not able to provide grain yield due to high panicle sterility (r). The two types of rice lines are IRIT184 and HHZ 14-SAL19-Y1. The results of the study indicate the need for farming technology intervention to increase the productivity of rice-fish farming to obtain optimal rice yield.

References

Adiwijaya D., Sapto P. R., Sutikno E., Sugeng, Subiyanto, 2003 [Cultivation of vannamei shrimp (*Litopenaeus vannamei*), an environmentally friendly closed system]. Department of Marine Affairs and Fisheries, Jepara Brackish Water Cultivation Development Center, 29 p. [In Indonesian].

Ahmad T., 1988 [Important variable water quality of shrimp pond]. Balai Penelitian Budidaya Pantai Maros, 56 p. [In Indonesian].

Ahmad T., 1992 [Management of water quality which is important for fish farming]. Balai Penelitian Perikanan Budidaya Pantai, Maros, 43 p. [In Indonesian].

Azman K., 2005 [The study of river water based on chemical analysis and diversity of algae.] University Teknologi Malaysia, Malaysia, 118 p. [In Indonesian].

Boyd C. E., 1990 Water quality in ponds for aquaculture. Auburn University, Auburn Alabama, 482 p.

Boyd C. E., 1992 Shrimp pond bottom soil and sediment management. In: Proceedings of the special session on shrimp farming. Wyban J. A. (ed), pp. 166-181, Word Aquaculture Society, Baton Rauge, L.A., USA.

Briggs M., Smith S. F., Subasinghe R., Phillips M., 2004 Introduction and movement of *Penaeus vannamei* and *Penaeus stylirostris* in Asia and the Pacific. RAP Publication 92 p.

Chang P. S., Tasi D. H., Huang C. Y., Wang C. H., Chiang H. C., Lo C. F., 1996 Development and evaluation of dot blot analysis for detection of white spot syndrome Baculovirus (WSVB) in *Penaeus monodon*. Fish Pathology 33(2):45-52.

Cholik F., Poernomo A., 1987 [A preliminary experiment on tiger prawn culture (*Penaeus monodon* Fabr.)]. Inland Fisheries Research Institute Report, 7 p. [In Indonesian].

Clifford H. C., 1994 Semi-intensive sensation: A case study in marine shrimp pond management. World Aquaculture 25(3):10-17.

Darmono, 1991 [*Penaeus* shrimp cultivation]. Penerbit Kanisius, Yogyakarta, Indonesia, 22 p. [In Indonesian].

Djukri, 2009 [Salinity stress on plant growth]. Proceedings of the National Seminar on Research, Education and Application of Mathematics and Natural Sciences, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Indonesia, pp. 49-55. [In Indonesian].

Effendi H., 2003 [Water quality assessment for resource management and the aquatic environment]. Kanisius, Yogyakarta, Indonesia, 258 p. [In Indonesian].

Eviati, Sulaeman, 2009 [Chemical analysis of soil, plants, water and fertilizers]. Technical Guidance Issue 2, Indonesian Soil Research Institute, Bogor, Indonesia, 136 p. [In Indonesian].

Flegel T. W., 1996 A turning point for sustainable aquaculture: the white spot virus crisis in Asia shrimp culture. Aquaculture Asia 1:29-34.

Hakanson L., Bryann A. C., 2008 Eutrophication in the Baltic Sea present situation, nutrient transport processes, remedial strategies. Springer-Verlag, Berlin Heidelberg, 263 p.

Haliman R. W., Adijaya S. D., 2005 [Vannamei shrimp, sultivation and market prospect of disease resistant white shrimp]. Penebar Swadaya, Jakarta, Indonesia, 75 p. [In Indonesian].

Hardie M., Doyle R., 2012 Measuring soil salinity. In: Plant salt tolerance. Shabala S., Cuin T. A. (eds), pp. 415-425, Humana Press, Totowa, NJ.

Hudi L., Shahab A., 2005 [Optimization of the productivity of vaname shrimp (*Litopenaeus vannamei*) culture using response surface and non-linear programming methods]. Prosiding Seminar Nasional Manajemen Teknologi II Program Studi MMT-ITS, Surabaya, 9 p. [In Indonesian].

Kono T., Savan R., Itami T., 2004 Detection of white spot syndrome virus in shrimp by loop-mediated isothermal amplification. Journal of Virological Methods 115:59-65.

Madeali M., Atmomarsono M., Muliani, Tompo A., 2009 [The effect of total organic matter concentration on the pathogenicity of *Vibrio alginolyticus* bacteria in tiger shrimp]. Prosiding Seminar Nasional Tahun VI., Hasil Penelitian Perikanan dan Kelautan Tahun, Bio-teknologi Perikanan, Yogyakarta, Indonesia, 6 p. [In Indonesian].

Mansur H., Syarianah, Dalfiah A., Rosmiati, Anshar, Husain, 2004 [Annual report 2004 of brackish water aquaculture research centre]. Center for Aquaculture Research. Marine and Fisheries Research Agency, Ministry of Marine Affairs and Fisheries, 59 p. [In Indonesian].

Moore J. W., 1991 Inorganic contaminants of surface water. Springer-Verlag, New York, 334 p.

Mustafa A., Mangampa M., 1990 [Tiger prawn culture using fry stunted with different period]. Jurnal Penelitian Budidaya Pantai 6(2):35-44. [In Indonesian].

Pascual F. P., 1984 Nutrient and feeding of sugfo, *Penaeus monodon*. UNDP/FAO Network of Agriculture Centre in Asia, Philipines, 34 p.

Poernomo A., 1988 [Making of shrimp ponds in Indonesia. Development Series No. 7]. Balai Penelitian Perikanan Budidaya Pantai, Maros, 40 p. [In Indonesian].

Poernomo A., 1989 [The dominant environmental factor in intensive shrimp farming]. In: Aquaculture. Bittner A. (ed), pp. 66-120, Budidaya Air, Yayasan Obor Indonesia, Jakarta. [In Indonesian].
Rachman A., Dariah A., Sutono S., 2018 [Management of saline rice fields with high salt content]. Iaard Press, Jakarta, Indonesia, 60 p. [In Indonesian].
Rajendran K. V., Vijayan K. K., Santiago T. C., Krol R. M., 1999 Experimental host range and histopathology of white spot syndrome virus (WSSV) infection in shrimp, prawns, crabs and lobsters from India. Journal of Fish Diseases 22:183-191.
Rukyani A., 2000 [The problem of shrimp disease and the hope for a solution]. Sarasehan Akuakultur Nasional, Bogor, Indonesia, 15 p. [In Indonesian].
Sawyer C. N., McCarty P. L., 1978 Chemistry for environmental engineering. McGraw-Hill Book Company, Tokyo, 532 p.
Schmittou H. R., 1991 [Cage cultivation: A fish production method in Indonesia]. Puslitbang Perikanan, Jakarta, Indonesia, 126 p. [In Indonesian].
Soetomo H. A. M., 2000 [Tiger shrimp cultivation techniques]. Sinar Baru Algensindo, Bandung, 180 p. [In Indonesian].
Sonmez S., Buyuktas D., Okturen F., Citak S., 2008 Assessment of different soil to water ratios (1:1, 1:2.5, 1:5) in soil salinity studies. Geoderma 144:361–369.
Sudrajat A., Wedjatmiko, 2010 [Shrimp cultivation in rice fields and ponds]. Penebar Swadaya, Jakarta, Indonesia, 76 p. [In Indonesian].
Sutanto J. T., Muhariyanto A., Krissunari D., Astuti Y., 2000 [Assessment of tiger shrimp cultivation technology]. Pusat Penelitian dan Pengembangan Sosial Ekonomi Pertanian, Bogor, pp. 573–585. [In Indonesian].
Suwarno, 1985 [Inheritance and physiology of salinity tolerant in rice]. PhD Thesis, Program Pasca Sarjana, Institut Pertanian Bogor, Indonesia, 87 p. [In Indonesian].
Tricahyo E., 1994 [Biology and culture of tiger shrimp (*Penaeus monodon*)]. Akademika Presindo, Jakarta, Indonesia, 128 p. [In Indonesian].
Umali D. L., 1993 Irrigation-induced salinity a growing problem for development and the environment. The Word Bank, Washington DC, USA, 78 p.
Wardoyo S. T. H., 1982 [Water quality criteria for agriculture and fisheries purposes]. ANDAL PPLH-PUSDI-PSL, IPB Bogor, Indonesia, 50 p. [In Indonesian].
Wickins J. F., 1976 Prawn biology and culture. Oceanography and Marine Biology Annual Review 4:435-507.
Zendstra H. G., 1997 Cropping systems research for the Asian rice farmer. Symposium on Cropping Systems and Development for the Asian Rice Farmer. IRR, Los Banos, Phillippines, pp. 11–30.
*** Canadian Council of Resource and Environment Ministers, 1987 Canadian Water Quality. Canadian Council of Resource and Environment Ministers, Ontario.
*** National Research Council, NRC, 1993 Nutrient requirements of fish. National Academic Press, Washington DC, USA, 114 p.

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